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TECHNICAL NOTE

Techniques for use of charcoal hemoperfusion in infants: Experience in two patients

BLANCHE M. CHAVERS, CARL M. KJELLSTRAND, CLIFFORD WIEGAND, JAMES EBBEN, and S. MICHAEL MAUER

Departments of Pediatrics and Medicine, The University of Minnesota Medical School, Minneapolis, Minnesota

Hemodialysis (HD) is used widely in the management of children with renal failure. The techniques and possible complications of HD treatment of infants and children have been well described [1]. Charcoal hemoperfusion (CH) has received extensive use in adult patients for the adsorption of a variety of exogenous and endogenous intoxicants [2, 3]. Initially, CH resulted in complications such as thrombocytopenia, charcoal embolism, leukopenia, fibrinogenopenia, and hypocalcemia. The incidence of these complications has been reduced markedly by the use of polymer-coated charcoal [4, 5]. There has been, however, little pediatric experience in the use of CH. This paper indicates that the procedure can be safely adapted for use even in the newborn period.

Methods

Patients[1]*: Patient 1.* A full-term 4-kg male with ornithine transcarbamylase deficiency developed extreme hyperammonemia unresponsive to conservative management. CH was used on day 4 of life. This patient died 6 months after CH due to sepsis.

Patient 2. A full-term 3.2-kg male with complex urologic anomalies requiring surgical drainage procedures was erroneously treated with excessive dosages of chloramphenicol (200 mg/kg/day). After the seventh dose of chloramphenicol, cardiovascular collapse (grey baby syndrome) developed. Thus, on day 13 of life, with a chloramphenicol level of 93 μg/ml, the patient underwent CH. This patient is alive and well.

Previously described techniques of monitoring vital functions and body weight were used [1]. A neonatal infrared warmer was used to ensure stable body temperature. Duration of the CH was 4 hours in patient 1 and 3 hours in patient 2.

Blood access. Blood access for extracorporal circulation in patient 1 consisted of an 8-French umbilical catheter placed into the right atrium via the right external jugular vein, serving as the blood exit line, and a 5-French umbilical catheter placed in the umbilical artery serving as the blood return line. Blood flow rate used was 25 ml/min. A CH column (Hemacol charcoal perfusion column, Warner-Chilcott, Morris Plains, New Jersey) containing granules coated with an acrylic hydrogel and the Gambro Mini-Minor dialyzer (Gambro, Lund, Sweden) were used.

Blood access for extracorporal circulation in patient 2 consisted of an 8-French umbilical catheter placed into the right atrium via the right internal jugular vein serving as the blood exit line, and a 5-French umbilical catheter placed in the umbilical vein serving as the blood return line. Blood flow rate used was 30 ml/min. A CH cartridge (Gambro Adsorba 300 C, Gambro, Lund, Sweden) containing granules coated with cellulose and the Gambro Mini-Minor dialyzer were used.

Circuit design. Charcoal hemoperfusion and HD were performed in sequence, the charcoal columns being placed before the dialyzers (Fig. 1). We used commercial dialysate solution containing 2.5 mEq/liter of calcium with 4 mg/dl of added phosphorus. Filters present at the inlet and outlet of the CH columns (Fig. 1) reduce the potential for embolization

[1] Separate case reports of both patients have been accepted for publication (See Ref. 10, 11).

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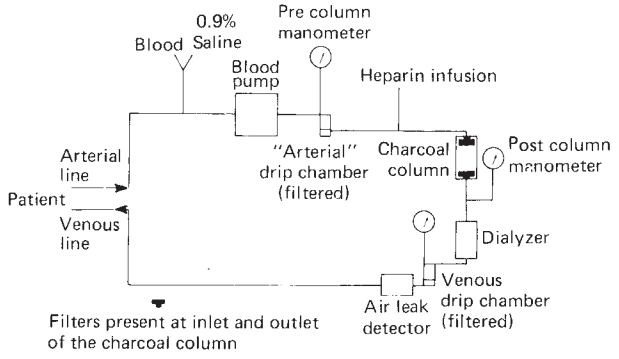

Fig. 1. *Circuit design for charcoal hemoperfusion in pediatric patients.*

of charcoal. Manometers were placed before and after the CH columns to measure pressure differentials across these devices. An increasing pressure differential would indicate clotting of the column. A third manometer was placed following the dialyzer to detect clotting of the dialyzer. An air-leak detector was placed distal to the venous-drip chamber.

Equipment priming. The CH columns were rinsed with 500 ml of a 5% dextrose solution followed by 2000 ml of heparinized (2 U heparin/ml) 0.9% sodium chloride. The total extracorporal volumes were 320 and 365 ml, including pediatric lines (35 ml), Adsorba 300 C cartridge (260 ml), Hemacol column (305 ml), and dialyzer (25 ml). Whole-blood priming was used. At the end of the treatment, the extracorporal blood was not transfused back.

Anticoagulation. Heparin (2 U) was added per milliliter of priming blood, and 80 U of heparin per kilogram of body wt were given as an i.v. bolus at the start of extracorporal flow. This was followed by continuous heparin infusion using 100 U/kg of body wt in 100 ml of 0.9% sodium chloride. An infusion rate of 0.5 ml/min provided 30 U of heparin per kilogram of body wt per hour. Lee White clotting times were kept at 40 to 50 min. Patient 1 was allowed to recover spontaneously from the heparin effect. Patient 2 received 2.5 mg of protamine in three divided doses to prevent bleeding from postoperative sites.

Table 1. Laboratory test results[a]

	Pre-CH	Post-CH	% Decrease
Patient 1			
WBC, *per mm*^{3}	3,800	3,100	18.4
Hct, %	37.6	37	1.6
Platelets, *per mm*^{3}	94,000	85,000	9.5
Ca, *mg/dl*	8.0	7.6	5
Patient 2			
WBC, *per mm*^{3}	12,300	7,600	38.2
Hct, %	30	36.5	—
Platelets, *per mm*^{3}	135,000	92,000 151,000 (8 hr post CH)	31.8
Ca, *mg/dl*	8.6	6.5 (obtained 8 hr post-CH)	24.4

[a] Abbreviations used are: WBC, white blood cell count per cubic millimeter; Hct, hematocrit; Ca, calcium; CH, charcoal hemoperfusion.

Results

Vital signs and body temperature did not deteriorate in either patient during the CH. There was no malfunction of the extracorporal circuits and no evidence of charcoal embolism. Both patients tolerated the CH well.

Patient 2 was noted to be acidotic and received i.v. sodium bicarbonate prior to CH. Acid-base studies 30 min into CH showed continued acidosis (serum bicarbonate, 9 mEq/liter), which responded to i.v. sodium bicarbonate and did not recur. In this patient, CH was associated with reversal of the shock state.

Depression of white blood cell and platelet counts occurred in both patients (Table 1). Platelet counts returned to pre-CH levels within 24 hours. Coagulation studies were normal at 12 hours following CH in patient 2. Patient 1 received further heparinization.

Serum calcium concentrations decreased during CH despite HD. Although symptomatic hypocalcemia did not develop, patient 2 received i.v. calcium gluconate for correction of hypocalcemia present following CH.

Over the course of the extracorporal treatment, the plasma glucose concentration increased from 66 to 129 mg/dl in patient 1. Posttreatment measurements were not obtained in patient 2, but clinical signs of hypoglycemia were not observed.

Discussion

We have demonstrated that CH can be performed efficiently and safely in infants. Using previously established methodology appropriately tailored to the needs of the infant [1], we had no technical problems during CH. This methodology involves the incorporation of equipment and procedures necessary to ensure stability of the small patient with special attention to: *(a)* close monitoring of vital functions; *(b)* continuous weight monitoring for the immediate detection of fluid shifts; *(c)* whole-blood priming of the circuit because, with presently available CH equipment, the extracorporal circuit volume greatly exceeds 10% of these patients' blood

volumes. With this technique we were able to prevent cardiodynamic instability.

The CH column should be rinsed with heparinized 0.9% sodium chloride to remove fine particles of charcoal and to allow heparin to adsorb to the charcoal particle surfaces, presumably reducing their thrombogenicity [3, 4, 6]. Dextrose rinsing of the CH column reduces glucose adsorption during CH [3, 6].

We placed a hemodialyzer in series with the CH column to minimize acid-base, electrolyte disturbances and hypoglycemia and to prevent hypothermia, which we feared might have been serious complications of the use of large charcoal columns in such tiny babies. Decreases in serum calcium concentrations occurred, however, in both patients, probably secondary to calcium adsorption by the CH columns [3]. It is also possible that depletion of serum calcium by the citrate in the donor blood used for priming of the extracorporal circuit occurred.

Thrombocytopenia secondary to platelet retention on the charcoal column and dialyzer membranes [4, 7] occurs in spite of adequate heparinization. Platelet loss is reduced to approximately 30% or less [2, 4, 8] with the use of coated CH columns. A 31% to 46% reduction in platelet count has been reported with HD [7]. A recent report on the use of CH in three children with Reye's syndrome suggested that the method is unsafe because of difficulty in detecting clotting in the CH column and significant depletion of coagulation factors [9]. Low flow rates and large CH columns were suggested as causal factors of perhaps greater significance than the coagulopathy intrinsic to Reye's syndrome. These children were treated with the B-D Hemodetoxifier, which consists of 94 g of uncoated charcoal affixed to polyester film and placed in a polycarbonate housing. The B-D Hemodetoxifier has less blood compatibility than either the Adsorba 300 C or the Hemacol column [8]. Therefore, the potential for thrombocytopenia is greater when the B-D Hemodetoxifier is used. Further, clotting in the extracorporal circuits, which occurred in the experience of Engle et al [9] and which could contribute to consumption of coagulation factors, was avoided in our patients. Thus, major depletion of coagulation factors needs not occur with use of the Adsorba 300 C or Hemacol CH columns if adequate heparization is used.

We have reported previously that ammonia clearances across the CH device in patient 1 was negligible compared with simultaneous aqueous hemodialysis where ammonia clearances approached blood flow rates [10]. We therefore concluded that CH was not indicated in the treatment of marked hyperammonemia. We found that CH (patient 2) was highly efficient in removing chloramphenicol from the blood [11]. Despite high serum concentrations entering the CH column, the concentrations leaving the device were so low as to be unmeasurable. Thus, comparison of CH and HD was not possible [11]. Other work, however, has shown that HD is relatively inefficient in clearing chloramphenicol [12]. In our view, the indications for CH in pediatric patients are similar to those in adults and should be considered in children with poisonings or drug overdosages who meet the criteria suggested by Winchester et al [3].

We conclude that CH can be performed without the development of serious complications when meticulous attention is given to technical details. Problems that must be overcome in the application of presently available CH equipment to the infant or small child include difficulty in blood access and the large size of this equipment relative to that of the child. A 100-g Hemacol charcoal column is presently available for clinical use only in England. A 150-g charcoal cartridge developed by the Gambro Company is presently being evaluated in Europe and in the USA but is not commercially available at this time. It is hoped that this report will stimulate the development of CH columns in sizes tailored more appropriately to pediatric patients. We believe this would further diminish the risks associated with the application of this important therapeutic modality to the pediatric patient.

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Reprint requests to Dr. B. Chavers, Department of Pediatrics, Nephrology Division, Box 491, Mayo Memorial Bldg., University of Minnesota Hospitals, Minneapolis, Minnesota 55455, USA

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